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METEOROLOGICAL AIRBORNE DATA SYSTEM

Donald A. Kahle

Joseph T. Swartzbaugh

University of Dayton
Research Institute
Dayton, Ohio 45409

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13. ABSTRACT

This report describes the Meteorological Airborne Data System (MADS) and the associated computer data processing program, explains why the system was developed, and points out the advantages of such a system. The MADS concept was developed to fulfill the need for the collection of a large number of meteorological and related data measurements and to provide a means for the rapid conversion of the raw data into useful information for the scientist. The underlying philosophy for the system design was that it be a very usable system under field data collection conditions and that it provide the scientist with data in the simplest form useful to him and do so within a very short time period. The hardware evolving from the design will record a maximum of 52 data inputs, has a maximum rate per input of eight samples per second, produces a computer-compatible tape, and operates in a noncontrolled aircraft environment. The software provides for editing of the recorded data, application of sensor calibration information, the computation of directly measured and derived meteorological parameters, and the generation of magnetic tape for automatic plotting of the data.

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INTRODUCTION

For a number of years, the Air Force Cambridge Research Laboratories have utilized aircraft in the collection of meteorological data. As emphasis on meteorological research has increased in recent years, more airborne instruments have been devised and research programs have become more sophisticated. The consequent demand for more data has, in many instances, put a strain on the capacity of older data collection methods. Equally important, the increased use of the digital computer in data analysis has created an interface problem between the function of data collection and data processing. The University of Dayton Meteorological Airborne Data System (MADS) is designed to fulfill this need for an accurate, versatile, high volume, quick turnaround data recording and processing system.

The MADS is a digital magnetic tape recording system with complementary computer software. The signal conditioning and tape recording equipment will operate in a noncontrolled environment of a high altitude aircraft and provides for the recording in computer-compatible digital form, of a maximum of 52 analog inputs and 13 event inputs. The computer programs provide for editing, calibration, smoothing, and various calculations to yield the location of the aircraft and the common meteorological parameters. Specialty subroutines may be integrated with the programs to accomodate the computations required by specialized instrumentation.

The outstanding advantage of the MADS is that the entire system (hardware and software) was designed specifically as an integrated system for the collection of data at field locations and the rapid conversion of the data into useful information. The key to the usability of the hardware is the playback electronics unit which not only permits diagnostic tests and calibration of the airborne equipment, but also provides for the field playback, in analog form, of the digital tapes. This unit combined with a custom specified analog recorder and a tape playback machine produces, in a matter of minutes, an analog, condensed picture of each recorded parameter. This permits an almost immediate assessment after a data collection mission of the functioning of the hardware and the approximate values of the raw data. This feature is invaluable in the success of data collection efforts.

The computer compatibility of the recorded tape together with the integrated computer programs produce the other main advantage of the MADS. The ability to reduce the recordings to readily usable information not only provides a further check on the conduct of the experiments, but permits the scientist to give consideration to the results of his programs while all the details are fresh in his mind.

SECTION 2

HARDWARE

The hardware portion of the MADS consists of two basic parts: the airborne system and the ground playback system. A description of each is provided below and summary specifications are presented in Appendix A.

2.1 AIRBORNE SYSTEM

The function of the airborne equipment is indicated by the simplified block diagram in Figure 1. The airborne system consists of three units: a signal conditioning or electronics unit, a tape transport unit, and a cockpit control panel. The first two of these are shown in Figures 2 and 3, respectively. The electronics unit provides the interface with the aircraft and has connectorc for power, control, and signal wiring. These two units are housed in rugged cases suppliea with hinged covers having moisture and RFI seals and quick-release latches. External controls on the electronics unit include an OFF-STANDBY-RECORD switch, flight identification (date) selector switches, a calibration switch, and tape transport controls. The tape transport unit has an internal dust cover so that exposure of the tape deck to the elements during preflight is minimized. The tape unit is supported in the aircraft on shock-mounts to reduce the possibility of vibration affecting the recording function. Heaters are also provided to maintain the temperature of the tape deck during flight. The cockpit control panel allows the aircraft crew member to turn the data system on and off, to determine if it is recording data, and to record specific events.

The airborne equipment operates on 115V, 60-400 Hz power and uses 28V DC for control purposes. The playback electronics provide the 28V control power when the equipment is operated in the laboratory. This feature permits the system to be operated in the laboratory on 60 Hz power for checkout and setup purposes, and also makes it possible to use the equipment for ground-based data collection without the necessity for power conversion devices.

2.1.1 <u>Electronics Unit</u>

The electronics unit provides all the functions of the data collection system except the actual recording on magnetic tape. The general functional groupings are indicated in Figure 1.

2.1.1.1 Signal Conditioning

Signal conditioning consists of converting differential floating input signals or single-ended signals in the range of 0.10 to 5 volts full scale into a standardized 10-volt level for the A-D converter. In addition,

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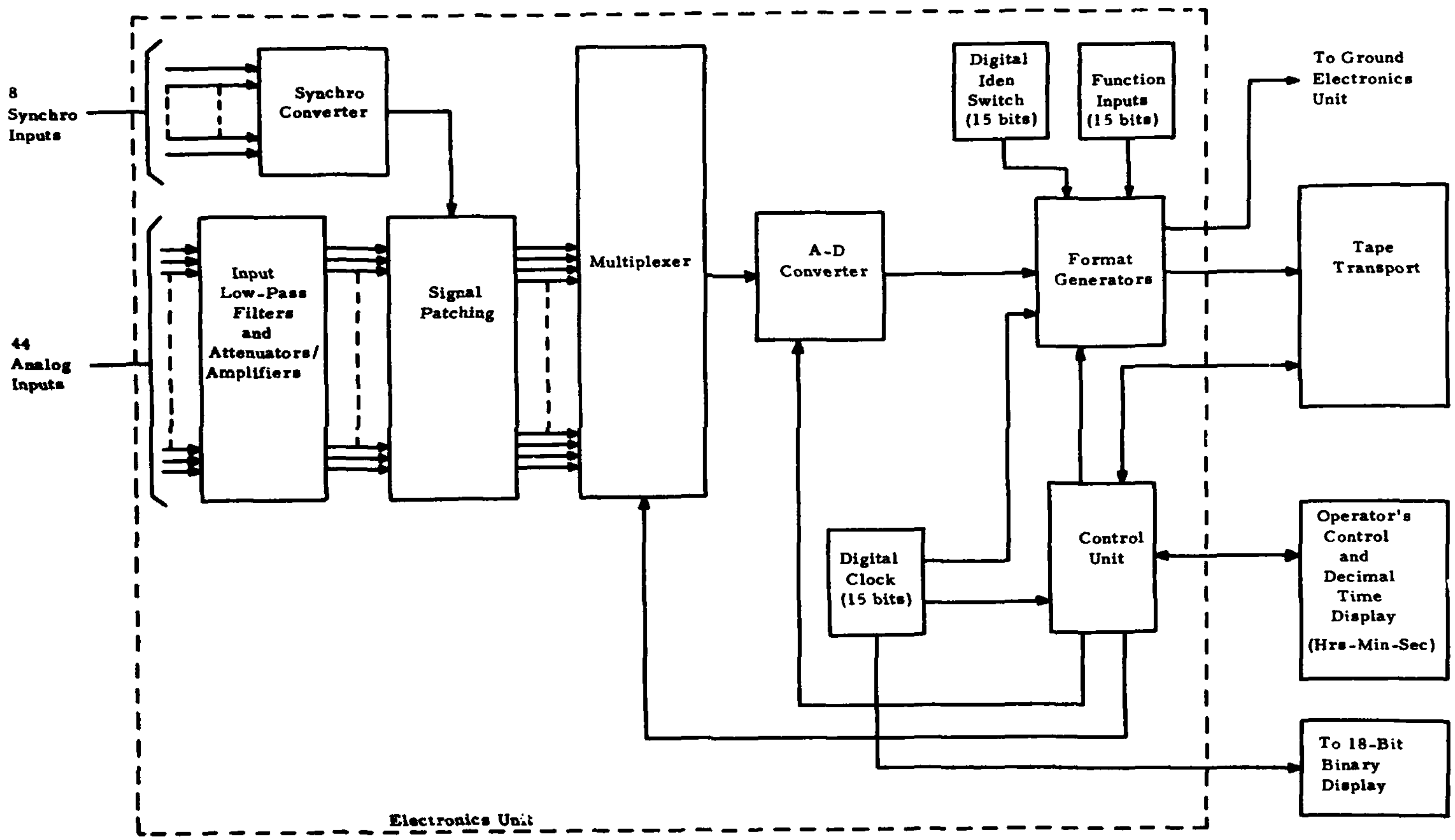

Figure 1. Simplified Functional Diagram of Airborne Data Collection System

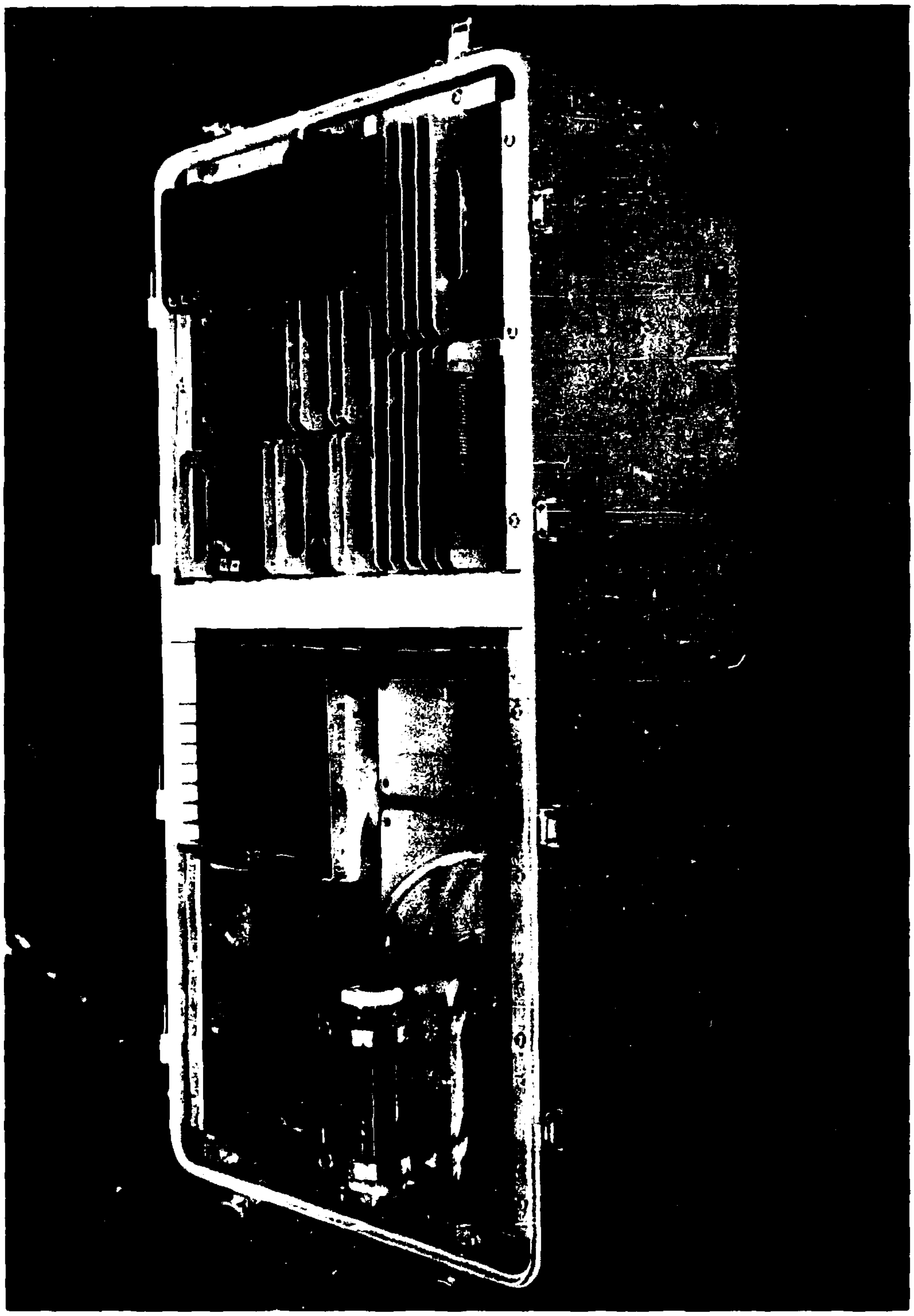

Figure 2. Airborne Electronics Unit

Figure 3. Airborne Tape Transport Unit

low pass filtering is incorporated in each signal conditioner to reduce noise and unwanted frequencies and the resultant aliasing errors. Screwdriver controls are provided on each signal conditioner card to adjust gain and CMR, and provision is made to offset the amplifier for bipolar inputs.

An inflight calibration-scheme is provided to check on signal conditioner performance during periods of changing environment. Solid state switching of the amplifier input from the signal source to a two-level, well-regulated reference voltage accomplishes this function. Resistors are used to match the calibration voltage level to each amplifier and to simulate the impedance of each signal source. The initiation of a calibration sequence is accomplished by means of an external timer or contact closure; however, the timing of the switching to the calibration voltages is synchronized with the data frames to yield four frames of zero level and four frames of calibration voltage at the beginning of a tape record. In order to minimize the calibration time, these eight frames are written at the rate of two frames per second regardless of the frame rate being used. All input switching takes place during the 62.5 msec allotted for the IR gap at the end of each frame.

2.1.1.2 Signal Patching

Provision is made for the connection of any of the 44 analog voltage inputs or the eight synchro inputs to any or all of the 52 multiplexer inputs. All patching is hard wired on a plug-in program board to allow for quick change of data format. On the program board, the single-ended output of each amplifier is wired to a multiplexer input. For the synchro channels, the synchro converter output is wired to all the appropriate multiplexer inputs and the converter input multiplexer gates are connected to appropriate frame format strobe signals.

2.1.1.3 Multiplexer

The multiplexer, under control of the clock, connects the 48 analog inputs to the sample-and-hold portion of the A/D converter in sequence as shown by the frame format in Figure 4. Each frame (multiplexer scan) is completed in one-half second and consists of 56 words (data samples) of 7.8125 msec duration each. The digital data occupies four word spaces and its position in the frame is fixed. The arrangement of Figure 4 is used to indicate that, with a uniform time between samples, it is possible to sample eight inputs four times per frame, eight inputs twice per frame, and four inputs once per frame. The 62.5 msec interrecord gap time interval is provided at the end of each frame. The system may be programmed to repeat the frame at 120, 60, 12, 4, 2, 1 frames per minute, or one frame per two minutes. The program connections are brought out to an external connector on the electronics unit. In order to avoid any frame-to-frame carryover of a loss of multiplexer synchronization, a signal resets all multiplexer gates

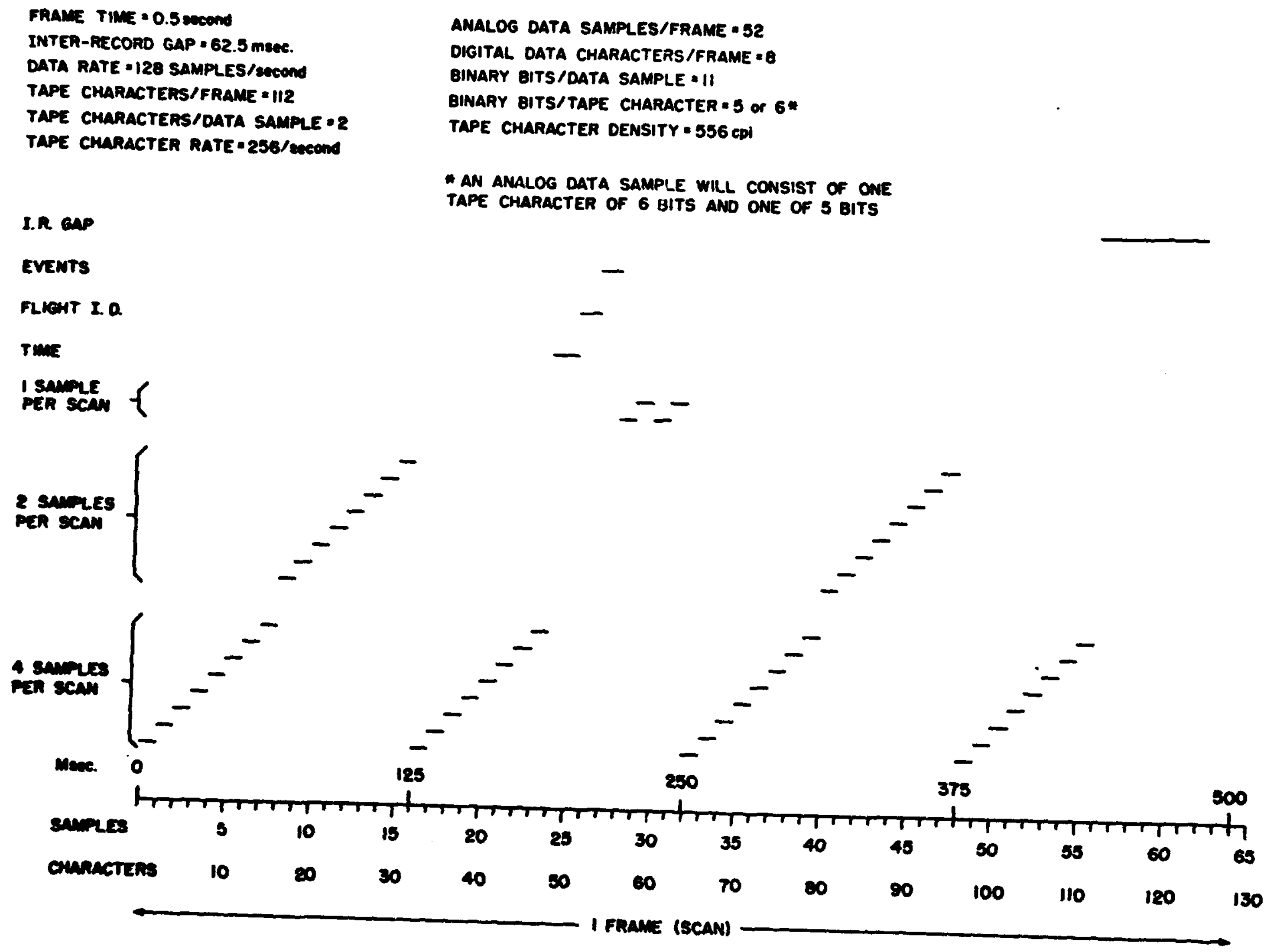

Figure 4. Frame Format

to the beginning-of-frame condition during the time provided for the interrecord gap.

2.1.1.4 Data Conversion

Two data conversion devices are used in the system: a synchro-to-DC converter and an analog-to-DC converter. The synchro/DC converter is an eight-channel multiplexed device that converts synchro angles of 0 to 360 degrees into a DC voltage of 0 to 10 volts. The output of this device goes to the program board where it is routed to the appropriate multiplexer inputs. The A/D converter is a successive approximation type which accepts the 0 to 10 V DC single-ended signals from the multiplexer and converts them into an 11-bit binary number. Timing of the operations of the converter is controlled by the system clock. An integral part of the A/D converter is the sample-and-hold circuit which clamps the multiplexer output after an appropriate settling time and holds the level until the A/D conversion is completed.

2.1.1.5 Digital Clock

The digital clock is a plug-in, self-contained unit that contains the crystal time base, the frequency division circuitry, the time-of-day accumulator, and a rechargeable battery. The unit plugs into the airborne electronics unit during system operation and is powered (and has the battery charged) by the data system. The clock will operate for 60 minutes on its internal battery and this permits it to be removed from the electronics unit and connected to the playback electronics unit for setting and readout of the time-of-day accumulator. The accumulator provides time in the 24-hour code in hours, minutes, seconds, and one-half seconds and is controlled by a 1.048576 M Hz crystal.

2.1.1.6 Digital Inputs

The digital inputs consist of the flight identification data and 15 event markers. The flight identification is encoded by means of a five-decade thumbwheel switch located on the outside of the electronics unit. The flight data is represented by two digits for the month, two for the day, and one for the year. Encoding each digit with the minimum number of binary bits results in a 15-bit identification. One of the 15 event bits is controlled by the EVENT switch on the cockpit control panel, and two are used to indicate when the system is in a high- or low-calibration mode. The control for the remaining twelve bits is brought out to connectors on the electronics unit case. Returning one of these lines to ground by means of a switch closure causes a "1" bit to be written in the appropriate position on the tape.

2.1.1.7 Control Unit and Format Generator

The control unit and format generator essentially provide the control of all elements of the system and format the digital data for recording on the magnetic tape. Control functions include the generation of timing signals for the multiplexer, A/D converter, and tape recorder and the interchange of commands with the tape machine. The format generator accepts the digital information from the identification switches, function or event inputs, and the A/D converter and arranges it in the form shown in Figure 5. As shown, each 11-bit data word is recorded as one six-bit and one five-bit character. The digital input data is fit into the format to conform to the frame format (Figure 4) and the space available.

2.1.2 Tape Transport

The tape transport records incrementally in the seven-track IBM format including odd parity, interrecord gaps, LRC character, and end-of-file space and mark. The unit is a Peripheral Equipment Corporation 1000 Series incremental write machine. It utilizes an optical encoder on the capstan shaft and a servo-controlled capstan motor to achieve uniform character spacing. The control circuitry in the electronics unit provides signals to the tape unit to tension the tape and bring the transport to the READY condition when the airborne system is switched to STANDBY.

2.1.3 Cockpit Control Panel

The cockpit control panel consists of a time display, control switch, event switch, and indicator lights mounted on a standard 5-3/4 inch-wide aircraft control panel with captive Dzus fasteners, and a behind-the-panel enclosure with suitable cable connector. The time display is a six-digit, one-plane, rear-projection, digital readout in the 24-hour time code. Brightness and contrast of the display permit reading under daylight conditions and there is no flicker of the digits.

The control switch provides OFF, STANDBY, and RECORD positions. In the STANDBY position, the entire system is enabled except for the tape motion, which is initiated by switching to the RECORD position. The control circuitry is arranged so that movement of the switch from the RECORD to the STANDBY position will cause the tape transport to stop at the end of the next interrecord gap. This allows complete records to be written on the tape and eliminates data rejection by the computer. Movement of the switch to the OFF position requires that the knob be depressed so that accidental turn-off in midrecord is reduced. The event switch is a momentary push-button device and each depression of the switch causes one "1" bit to be recorded in the appropriate location on the tape. Two push-to-test indicator lights are provided; one to indicate that the system is ready to record, and the other to indicate that data recording is taking place.

TRACK	CHARACTER 1	2	3	4....	49	50	51	52	53	54	55	56	57	58....
C	As Required													
B	D-1	D-7	D-1	D-7	H-1	M-1	S-1	M-1	D-1	Y-1	E-4	E-10	D-1	D-7
A	D-2	D-8	D-2	D-8	H-2	M-2	S-2	M-2	D-2	Y-2	E-5	E-11	D-2	D-8
8	D-3	D-9	D-3	D-9	H-3	M-3	S-3	M-3	D-3	Y-3	E-6	E-12	D-3	D-9
4.	D-4	D-10	D-4	D-10	H-4	M-4	S-4	M-4	D-4	Y-4	E-7	E-13	D-4	D-10
2	D-5	D-11	D-5	D-11	H-5	M-5	S-5	M-5	D-5	E-2	E-8	E-14	D-5	D-11
1	D-6		D-6		S-7	M-6	S-6	E-1	D-6	E-3	E-9	E-15	D-6	
	DATA WORD		DATA WORD		TIME			DATE			EVENTS		DATA WORD	

D = Data, Day
H = Hour
M = Minute, Month
S = Second
Y = Year

E1 = Pilot's Event, "1" = Event
E2 = Cal Hi, "1" = Cal Hi
E3 = Cal Low, "1" = Cal Low
E4 - 15 = External Event Inputs
1 = Most significant bit

Figure 5. Tape Format

2.2 PLAYBACK SYSTEM

The block diagram of Figure 6 indicates the functions performed by the playback system. The system consists of three major components: the electronics unit, the tape transport, and the analog recorder. The equipment performs three functions. Primarily it is used to convert digital tapes into analog recordings. Secondly, the electronics unit is used in connection with the airborne system to perform checkout and calibrations. In addition, the electronics unit provides for the setting and the readout of time on the digital clock.

2.2.1 Electronics Unit

The electronics unit, shown in Figure 7, performs the various decommutation and conversion functions and provides the data displays. The unit is housed in a rugged case with hinged cover and operates on 115 V, 60-400 Hz power to facilitate use either with the aircraft or in the laboratory.

2.2.1.1 Decommutator and Output Selector

The function of the decommutator is to extract from the data format the three characters containing the time information, the five characters containing the flight identification and event information, and the 104 characters containing the data. The decommutator operates at a maximum real-time rate of 256 characters per second or at the play-back rate of approximately 13,900 characters per second. Synchronization of the decommutator is based on the time allotted for the IR gap on the tape (62.5 msec every frame in real time, or 30 msec every 15 frames for playback). The decommutator, as indicated in Figure 6, has fixed outputs for the time, event, and flight identification displays and the character count, and it has nine selectable data outputs, and nine selectable event outputs. Each of the nine data outputs is assignable, by means of thumbwheel switches, to any of the 52 data words in the frame. Each of the nine event outputs is thumbwheel-switch assignable to any of the 15 events. In addition to the data and event outputs of the decommutator, a pulse output, at the rate of one pulse per 67 tape characters, is supplied to advance the incremental chart drive of the analog recorder.

2.2.1.2 Time Display and Clock Control

Provision is made to plug the airborne system clock into the electronics unit for setting of the time-of-day accumulators. Switches are provided to switch the clock to a "set" mode and to advance each decade of the hours, minutes, and seconds to the desired time. Throwing the switch to the "run" position allows the time to advance. A six-digit rear projection digital display is provided to read the clock time in hours, minutes, and seconds.

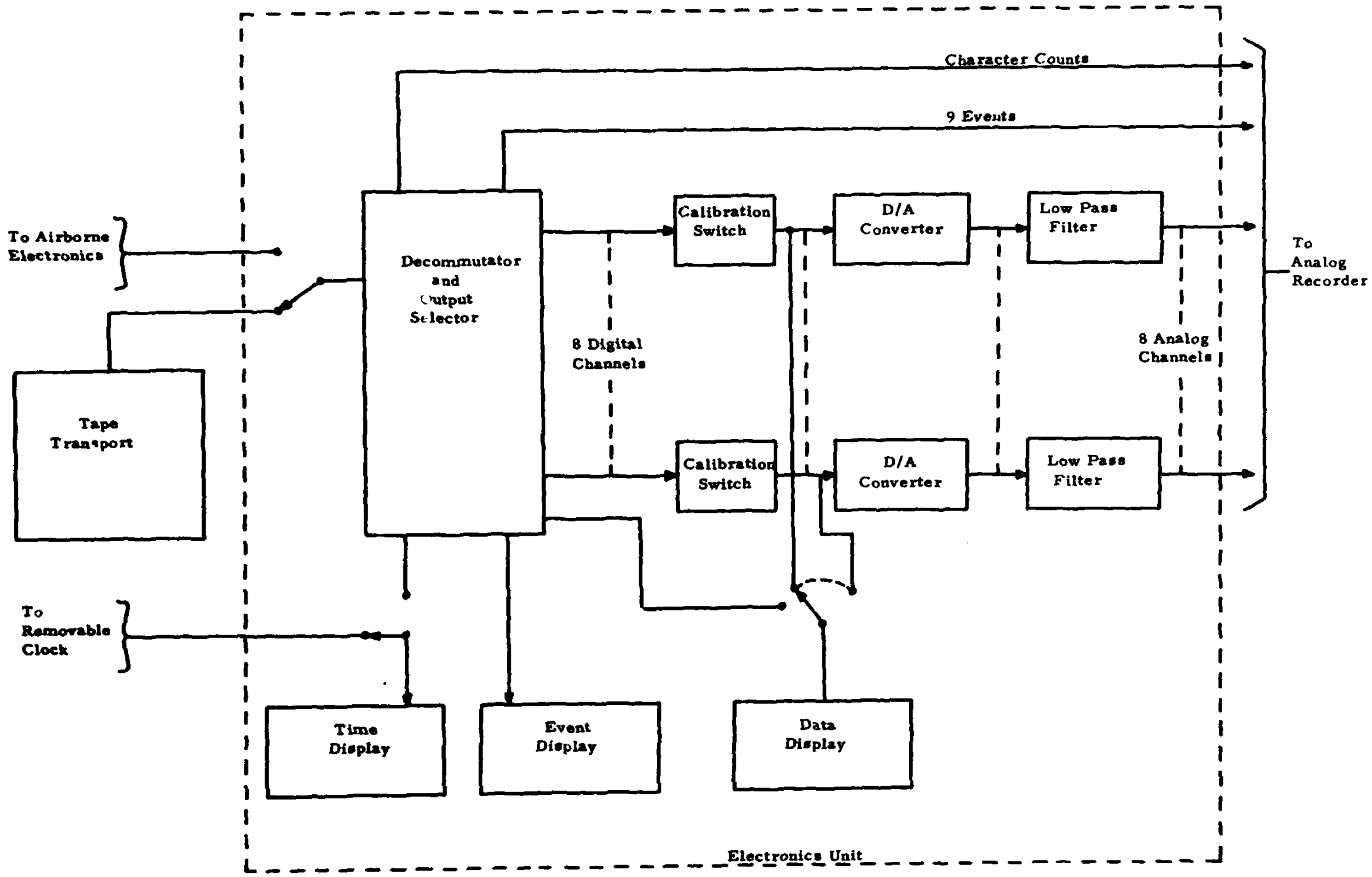

Figure 6. Simplified Functional Diagram of Play-Back System

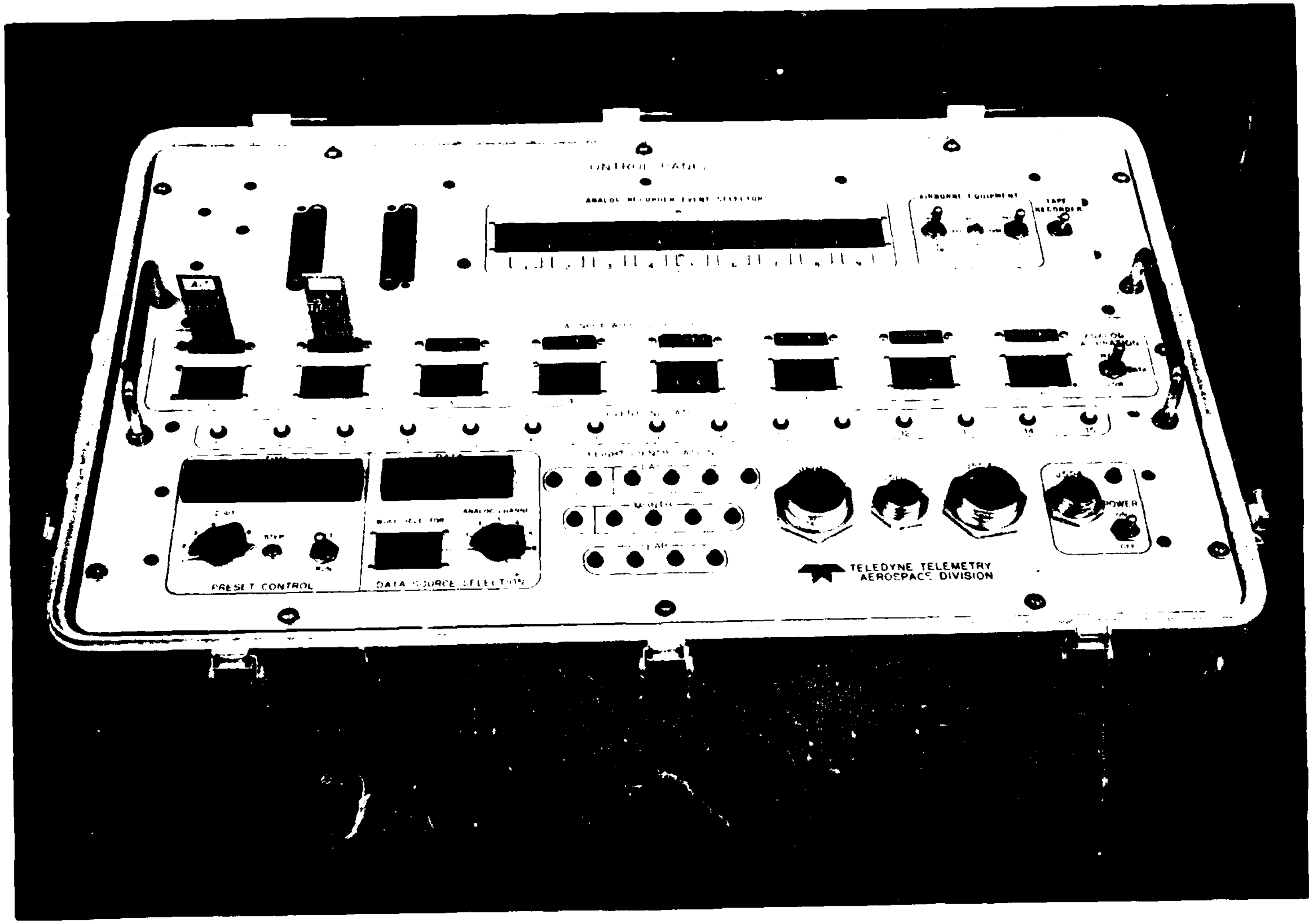

Figure 7. Play-Back Electronics Unit

2.2.1.3 Event Display

The event displays consist of two groups of 15 indicator lamps each. One group is arranged in a BCD format by DAY, MONTH, and YEAR to provide a readout of the flight identification. The other group of 15 lamps indicates which events are actuated. When any given event is continuous, there is no flicker of the indicator lamp.

2.2.1.4 Data Display

The data display is a four-digit, rear-projection, decimal readout capable of being connected to the word selector or to the input of any of the eight D/A converters. This allows readout of any of the 52 data words or of the D/A inputs, whether they be connected to the data or to the Cal cards. This feature permits checking of the encoding of the Cal cards. The data display incorporates a memory and update timer that provides updating of the display three times per second.

2.2.1.5 Calibration Cards

Switching is provided at the input to each D/A converter to allow one of three digital data sources to be connected to it. The switching for all eight D/A's is controlled simultaneously by one toggle switch. The primary source for each D/A is the data word selected by the individual thumbwheel switches. In addition, a two-sided printed circuit board is installed in a connector associated with each D/A. Each side of the card has provisions for encoding, in binary form, a seven-bit number. Either side of the card may be selected as input to the D/A. The purpose of this is to provide a means of calibrating the analog recorder channels for each data parameter. The digital value for the lower edge of the analog scale is encoded on one side of the card and the value for the upper edge on the other side of the card. By switching between the "Lo" and "Hi" Cal positions, the gain and pen position of each of the analog recorder channels may be set.

2.2.1.6 Digital-to-Analog Converters and Low-Pass Filters

The purpose of the eight D/A converters is to convert the seven most significant bits of the 11-bit binary data words to an analog voltage for the strip chart recorder. Since the resolution of data on the analog chart is only about 1%, only the seven most significant bits are converted. Low-pass filters with cutoff at 5 Hz are used on the output of the D/A converter to make the frequency response of the data compatible with the analog chart speed and thus eliminate fuzzy lines or "hash" on the analog recordings.

2.2.1.7 Control of Airborne Equipment

A switch is provided on the electronics unit that duplicates the functions of the OFF-STANDBY-RECORD switch on the cockpit

control panel. A push button is also provided to initiate an automatic calibration sequence. In addition, a toggle switch is included to put the airborne signal conditioners in a sustained low- or high-calibration mode. This feature permits setting of the amplifier gain and balance and makes it possible to read out the values of the calibration steps for data processing purposes.

2.2.2 Tape Transport

The playback tape machine is a Peripheral Equipment Corporation model 3510 synchronous read device. This transport operates at 25 inches per second which allows playback of one hour of flight data (recorded at two frames per second) in about one minute. As may be seen in Figure 8, the machine will accept 8-1/2" IBM-type reels, and has controls for loading the tape to BOT, and automatic rewind. The transport has no recording capability, thus eliminating the possibility of accidental erasure of a data tape.

2.3 ANALOG RECORDER

The analog recorder used for the quick-look playback is a Brush Instruments Mark 200 machine. Figure 9 is a photograph of the recorder as it is configured for on-site use. This configuration provides four channels each 40 mm wide and two channels each 80 mm wide on a 15-inch-wide chart paper. Writing is rectilinear using a pressurized ink system.

The pre-amplifiers supplied with the recorder provide a wide range of sensitivities and a zero suppression feature which permits the accommodation of any data parameter with any reasonable scale factors. Polarity reversal switches are included so that the zero line for any parameter may be put on either side of the chart regardless of the signal polarity.

The feature of the recorder that makes it particularly useful for this application is the incremental chart drive. The chart is advanced a given distance for each character on the magnetic tape. Thus, distance on the analog chart is directly related to real time during data recording on the magnetic tape, regardless of character spacing or speed of the tape during playback. Although a range of paper speeds is available by pushbutton selection, an appropriate speed is 5 mm of chart per minute of flight time (recorded at two frames per second). This scheme portrays one hour of flight data on about one foot of chart. Since only six data parameters can be displayed on one chart, it is usually necessary to make at least two charts of each flight tape. This scheme of chart speed control permits viewing the various charts in juxtaposition with essentially perfect time alignment from beginning to end.

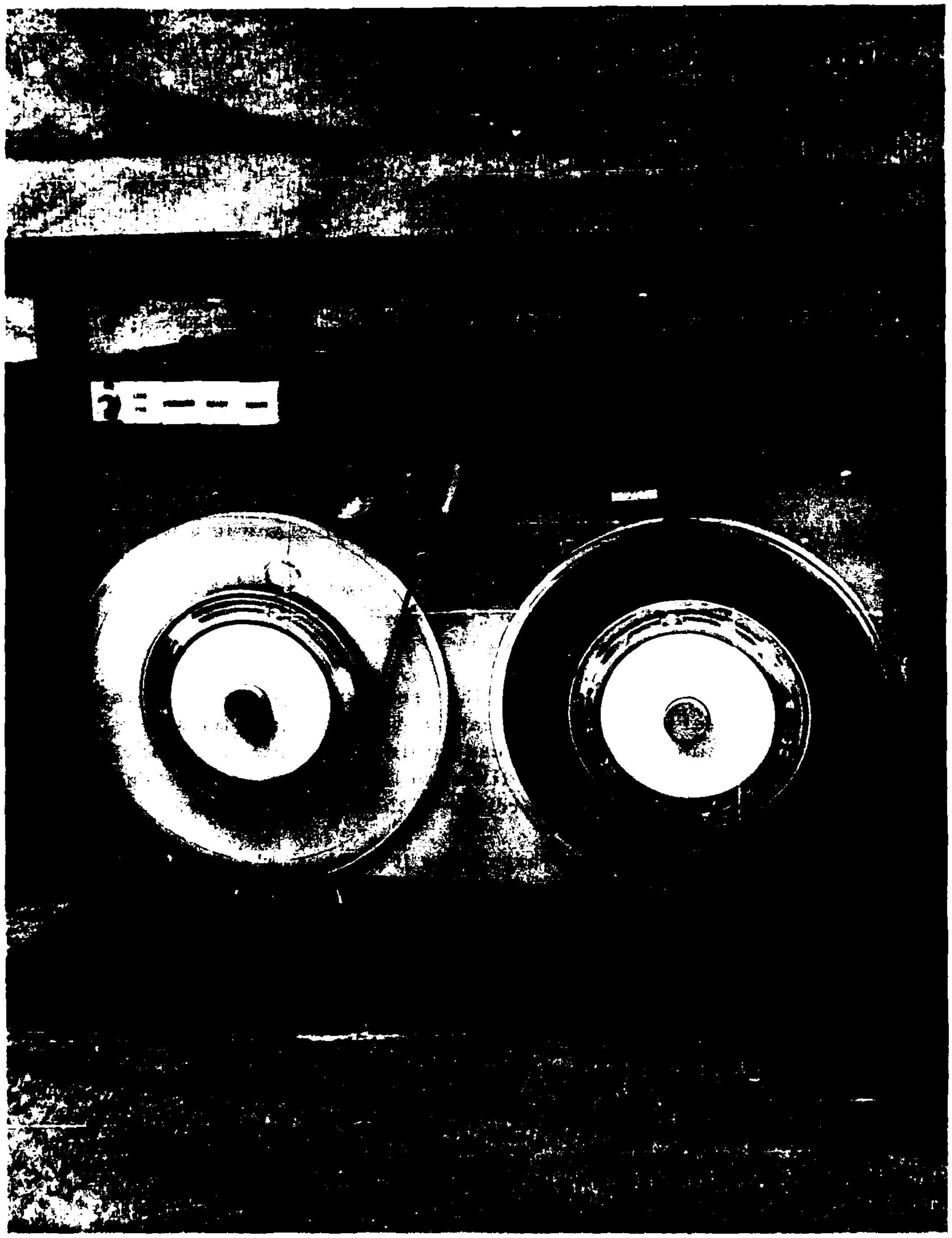

Figure 8. Play-Back Tape Machine

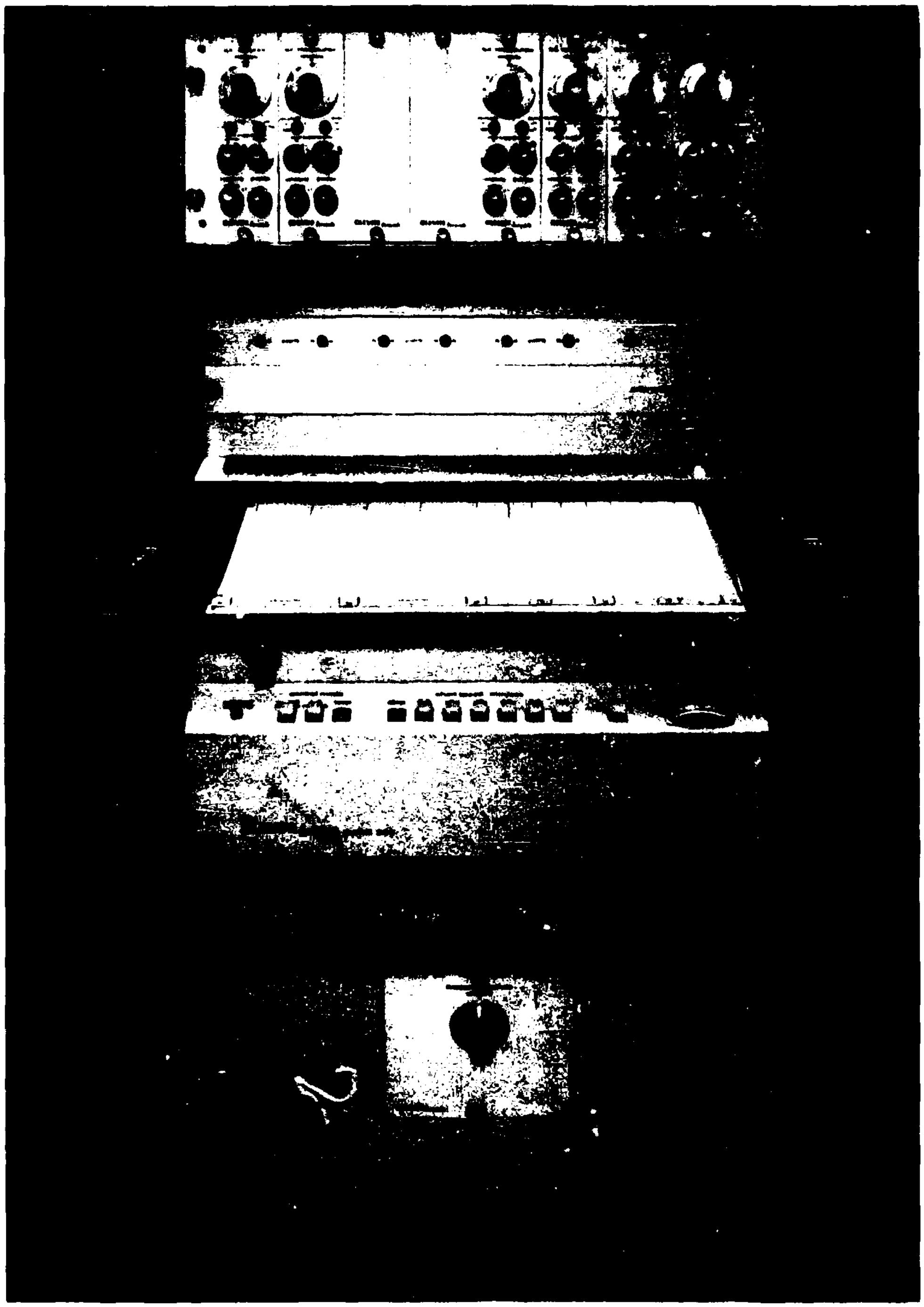

Figure 9. Analog Chart Recorder

In addition to the six data channels, there are seven event pens - one on each edge of the paper and one between each of the six data channels. These are used to record the event channels such as the pilot's event.

SECTION 3

MAIN DATA PROCESSING PACKAGE

It may be said that the MADS is analogous to an oscillograph recorder system wherein the digital airborne data tape is equivalent to an oscillograph record. Continuing the analogy, the Main Data Processing Software Package (MADS-1) is designed to replace the human oscillograph reader and thus to eliminate what was the greatest time lag and possibly the greatest error source in the oscillograph system. This software package is intended to produce rapid reduction of the measured data with no loss in the accuracy of the data as it is recorded. The primary input for MADS-1 is, of course, the airborne digital data tape. Since this tape is recorded in a highly compact format, the data contained thereon must be reformatted to be recognizable by the computer for any further use. This reformatted data is then calibrated using calibration information derived from subsidiary input in the form of calibration curves and from in-flight calibration checks. The resultant information is then read out in a form usable for further computations. Figure 10 is a flow chart representation of this routine.

The MADS-1 Data Reducer is an operation-oriented command interpreter. The five command words recognized by MADS-1 are UNPACK, CALIBRATE, PROCESS, UTILITY, and STOP. Immediately after each command, a corresponding input data set must be read.

3.1 THE COMMAND UNPACK

UNPACK instructs the program to reformat the airborne data tape. Options available within this segment of the routine include the ability to check the date and/or to check the time as recorded on tape against specified correct values. The option to print the reformatted data is also available. Card input which must follow the UNPACK command consists of the "labeled" input values:

DATE = m m d d y y or DATE = 0

INCR = X.X

PRINT = 'YES' , PRINT = 'NO' , or PRINT = 'SAMPLE'

DATE is the flight date expressed as (numerical) month, day, and year to which the date on the data tape is compared. If the DATE = 0 option is chosen, no checking is done.

INCR is the time increment for the flight and must be entered as a real number. It is used to check for incorrect and missing times. If INCR= 0.0 is specified, no checking will be done.

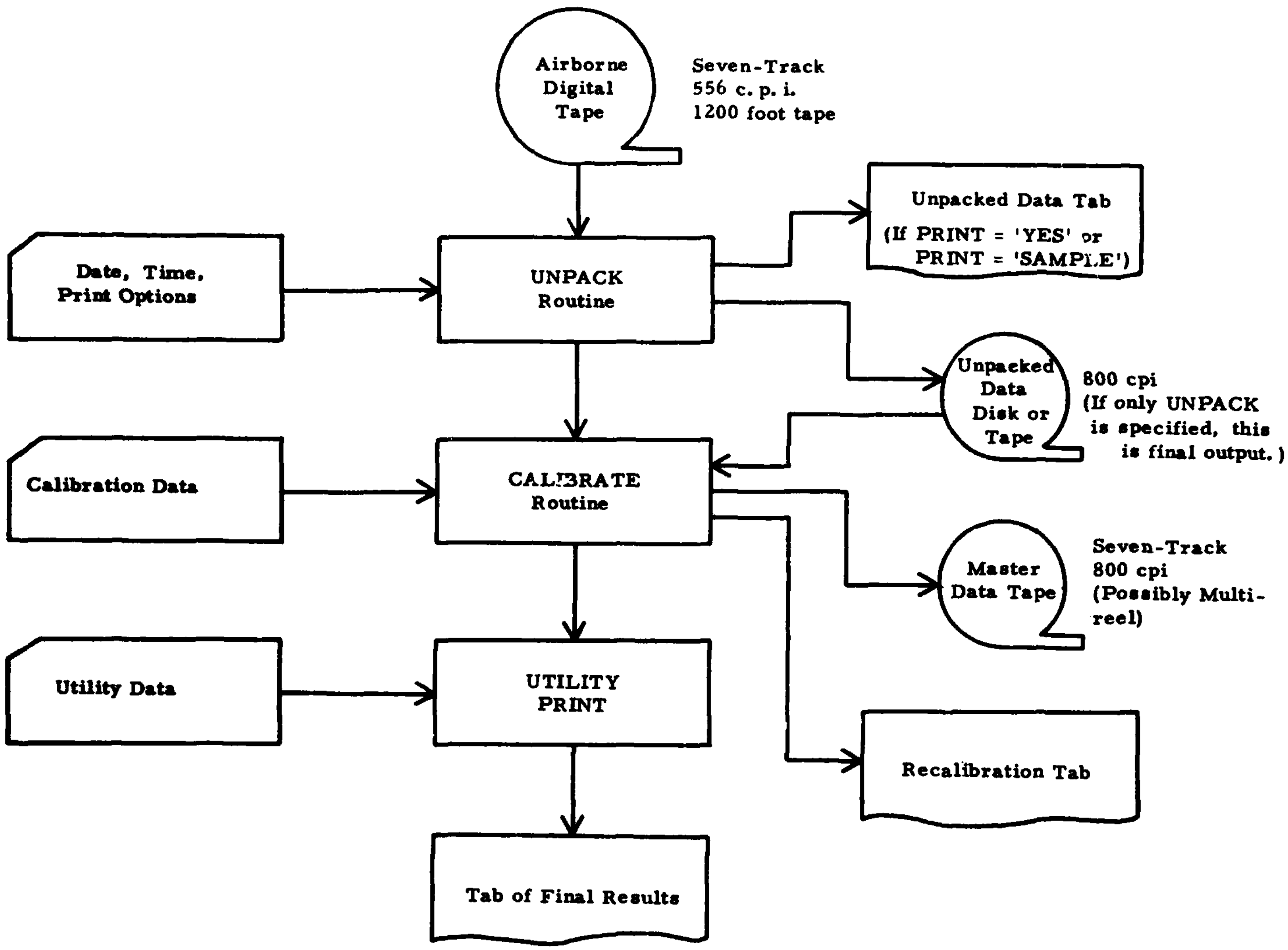

Figure 10. MADS-1 Logic Diagram

The PRINT option determines the frequency at which the reformatted (but uncalibrated) data will be printed. PRINT = 'YES' results in all of the data being printed; PRINT = 'SAMPLE' prints every 100th record; and PRINT = 'NO' inhibits printing of the reformatted data.

Input for these three options must be included and must be placed on a single card. They may be entered in any order on the card, but must be separated by a comma. Tutorial examples are included in the listing of sample inputs in Appendix B of this report.

The reformatted data resultant from this section of the program is then recorded on either disk or tape. If tape is used, then should subsequent portions of the program abort, this output tape may be used to run the remainder of the program later without repeating UNPACK.

3.2 THE COMMAND CALIBRATE

CALIBRATE instructs the program to input the calibration curves and associated information, to update the calibration curves as required, and to convert the data into proper engineering units. Card input following the CALIBRATE command consists of a collection of five types of data sets. These are the PARAM options, the EVENT parameters, the VARIABLE LOCATION parameters, the VARIABLE COMPARISON parameters, and the CAL-CURVE parameters.

The PARAM options cause MADS-1 to perform certain functions in order to provide greater flexibility or increased information. The PARAM options are specified by a labeled input parameter of the form PARAM = 'AAAA' where AAAA is the option chosen. The available options are:

- PRINT - causes the calibration curves to be printed after each in-flight recalibration.
- DUMP - causes the calibration information arrays to be printed.
- EXEC - causes the calibration routine to process the data. It is used only after all calibration data has been input.
- STOP - causes the calibration routine to return control to the main program without processing any data.

The EVENT data set informs the program which events are to be checked and what name is associated with each active event bit. The data set consists of the following two labeled input parameters for each active event bit:

EVENTNO	=	n	where n may go from 1 to 1r and is the number of the active bit of interest.
EVENT	=	'AAAA'	where AAAA is the name of the event to be printed.

Both of the above are required entries for every active event bit except events "2" and "3". Events number "2" and "3" are always the HICAL and LOCAL bits, respectively, and are thus always checked.

The VARIABLE LOCATION data set informs MADS-1 which variables are to be processed, where they are on the data tape, and which calibration curve is to be used with them. It consists of the following two labeled input parameters for each variable to be processed:

VARNO	=	n	where n is a number defining the position of the variable on the data tape. n can be any number from 1 to 52. This is a required entry.
CURVE	=	m	where m specifies which of the separately input calibration curves is to be used to calibrate the nth variable on the data tape. This also is a required entry.

The VARIABLE COMPARISON parameters are a set of descriptions to be used when the calibrated value of one recorded variable is to be compared with another. Such would be the case if some variable were to be determined using a multi-valued (segmented) calibration curve wherein one recorded value could correspond to many possible calibrated values for the parameter. The actual calibrated value of the parameter would then have to be determined by comparison with a more coarsely measured value of the same parameter recorded in another data position and having a single-valued calibration curve. The data set consists of a single card containing the following labeled input parameters:

SEG1	=	n	where n is the CURVE number of the appropriate unsegmented curve;
SEG2	=	m	where m is the CURVE number of the segmented curve;
SEGLIM	=	X.X	the range within which the values of the fine and coarse variables are to match;

SEGCON	= X.X.	a constant factor by which the calibrated value obtained from CURVEs n and m is multiplied.

Each of the above is a required entry and one such card must be entered for each multi-valued variable being calibrated. When this option is in force, the CALIBRATE routine will search through the values obtainable for the multi-valued variable which is different from the single-valued variable by an amount no greater than the specified RANGE.

The CAL-CURVE data set inputs one calibration curve into the MADS-1 program for each measured parameter. Each data set consists of a labeled input data set followed by a set of cards containing values for the parameter in digital counts as recorded on the digital data tape (called X values) and which is in turn followed by a set of cards containing the corresponding values of the parameter in proper engineering units (called Y values). For the case of a multi-valued parameter, the CAL-CURVE will be entered in segments with the set of X values repeated once for each segment with each X value set followed by the appropriate Y values for each possible value the multi-valued variable can take on.

The labeled input parameters are:

CALNO	= n	The calibration curve number as used on the calibration curves and in the variable location parameters. This is a required entry. n may have any value from 1 to 99.
LENGTH	= n	The number of x and y points in the calibration curve. This is a required entry.
HICAL	= X.X	The high calibration value associated with the curve. This is a required entry.
LOCAL	= X.X	The low calibration value associated with the curve. It is a required entry.
NAME	= ' '	The name of the variable to be reduced with the curve. If omitted, it is set to " " (blank).
UNITS	= ' '	The units of the variable to be reduced with the curve. If omitted, it is set to " " (blank).

FORMAT	= ' '	The output format associated with the reduced variable. If omitted, 'F8.3' is used.
PARTS	= n	The number of segments in the curve. If omitted, n = 1 is used.
ROUND	= X.X	The round-off factor used in the printing of the data. If equal to 0.0, no rounding occurs. If omitted, 0.0 is used.

The format for the X and Y point card is:

Cols. 1-2	-	The calibration curve number (CALNO = _____) - (I2)
Col. 3	-	An "X" or "Y" identification letter - (not checked by the program at this time).
Cols. 4-80	-	Curve points - 11 points in fields of seven characters - (F7.0).

The X points for the first segment are given first. The Y points for the first segment follow. The other segments (if any) follow in like order. The X and Y points are always on separate cards.

3.3 CALIBRATION APPLICATION

The method of calibration used takes into account the possibility of changes in the voltage levels during flight and thus the CAL-CURVES are updated regularly throughout the flight.

3.4 CALIBRATION INFORMATION

The calibration information will initially be available to the data processing personnel in the form of graphs of engineering units versus digital counts for each parameter of interest (for example see Figure 11). The counts in this case are the digitization of the input analog voltage calibration signals. In addition to this, at pre-flight check-out, an upper level (hi-cal) and a lower level (lo-cal) calibration signal will be input into the system for each parameter. These signals will correspond to certain high and low points on the initial calibration curve. Then throughout the flight these hi- and lo-cal voltage signals will be repeated occasionally as in-flight calibration checks. Each such calibration signal will be recorded on four successive frames. Because of low-pass filter ringing, the first frame will be ignored and the

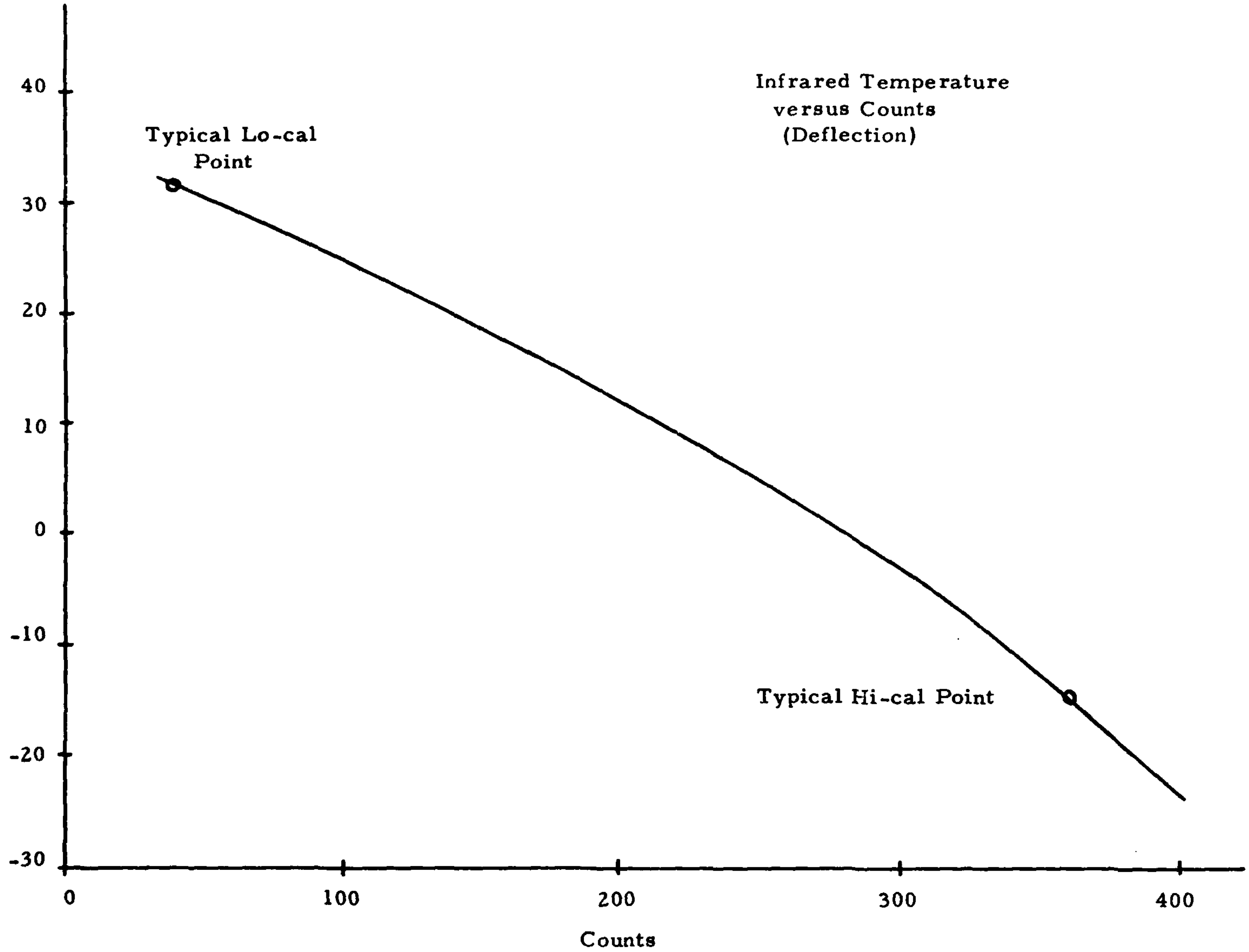

Figure 11. Sample Calibration Curve

value used as the cal-signal will be the average of the values recorded in the last three frames.

3.5 UPDATING CALIBRATION CURVES

First a sufficient number of equally-spaced points to adequately represent a calibration curve will be stored as an array in the computer. Each time an in-flight hi- and lo-cal check occurs, these stored calibration points will be adjusted to correspond to the new values. This method of adjustment will be as follows:

Let Δh equal the difference between the new and the original hi-cal values (in counts)

$\Delta \ell$ equals the difference between the new and the original lo-cal values (in counts) .

And if

H = original hi-cal value (in counts)

L = original lo-cal value (in counts),

we define

$$K = \frac{\Delta h - \Delta \ell}{H - L} \quad .$$

Then we replace each point X on the cal-curve by a new value X' defined by

$$X' = K(X-L) + X + \Delta \ell \quad .$$

At this point in the program, the new values in the calibration curve arrays are printed out together with the value in counts of the hi- and lo-cal signals and the clock time when they occurred.

In addition, should any in-flight recalibration point differ from the original calibration signal by more than 1%, an appropriate error message will print out to indicate the possible unreliability of this data channel. The measured parameters will then be calibrated using a quadratic interpolation method on the updated calibration curves.

3.6 THE COMMAND UTILITY

The UTILITY option instructs the main controller to execute the utility processor.

The input to the utility processor is the single labeled input parameter TYPE = ' '. To date there are two utility routines controlled by the processor. They are:

TYPE = 'END'	which instructs the processor to return control to the main program. It must be the last card of the utility input card deck.
TYPE = 'PRINT'	which causes the utility print routine to be executed.

The card input for the PRINT utility consists of a labeled input data set containing two parameters:

WIDTH = n	where n is the number of characters across a page - default = 132.
LINES = n	number of lines per page (lines before next heading is printed) - default = 62.

The input to the PRINT must be either CALIBRATE or EDIT output. A data tape may be printed more than once by successive TYPE = 'PRINT' statements.

3.7 THE STOP AND PROCESS COMMANDS

STOP instructs the main controller that you are ending processing of one run. This results in the program's checking to insure the proper conclusion of the processing and its initializing itself for the next run (flight). It has no associated card input.

The PROCESS command replaces the UNPACK and CALIBRATE instructions. The card input for these instructions are stacked together in the same order as the commands are listed above.

3.8 OUTPUT

Primary output of this stage of the processing is a master data tape which is to be a seven-track, 800 cpi, 2400-foot tape containing a time history of the measured parameters in proper engineering units. In addition to this, at user's option there can be a tabular listing of:

a) Start and stop time of the data.

b) Complete base calibration input.

c) In-flight recalibration data showing time of occurrence and the values in counts of the hi- and lo-cal signals, a complete listing of the updated calibration arrays resulting from these, and any error messages to check channel stability.

d) The maximum and minimum values of the parameters for use in establishing scale limits for output plots.

e) Total number of records on the Master Data Tape.

3.9 MADS-EDIT

The MADS-EDIT routine is a separate software package which allows the output from MADS-1 to be edited as the user desires. The input to MADS-EDIT is the following:

$\left.\begin{matrix} z_1 \\ z_2 \end{matrix}\right\}$	=	constants determining permissible ranges for standard deviation checks.
$\sigma_{expt.}$	=	expected value of standard deviation of first differences.
σ_{lo}	=	minimum allowable standard deviation of first differences.
N	=	number of points to be considered as a set.
N_0	=	maximum number of consecutive missing points to be replaced.
Δt	=	time difference between points.
M	=	maximum number of points to be replaced by sliding fit method.

The routine reads in N data points. As it does, it checks for any missing time points. If a point is missing, a value is inserted equal to the parameter's value at the previous time point. If more than N_0 consecutive points are missing, an error message is printed, the program goes to the next available time points, and considers this the beginning of a new data set.

When the program has N data points to work with, the first differences for these N points are found and the standard deviation, σ_{FD}, of these first differences is computed.

1. Check σ_{FD} against σ_{1o}.

   a) If $\sigma_{FD} \leq \sigma_{1o}$, set $\sigma_{FD} = \sigma_{1o}$, accept the N points as good points, read in next N points, and continue. Replace $\sigma_{expt.}$ by σ_{FD}.

   b) If $\sigma_{FD} > \sigma_{1o}$, go to next check.

2. Check σ_{FD} against $\sigma_{expt.}$.

   a) If $\sigma_{FD} \leq z_1 * \sigma_{expt.}$, accept N points as good and go on to next N points. Replace $\sigma_{expt.}$ by σ_{FD}.

   b) If $\sigma_{FD} > z_1 * \sigma_{expt.}$, check for outlying points in the following way:

      If $x_i - x_{i-1}$ and $x_{i+1} - x_i$ are of opposite sign and both are greater than $z_2 * \sigma_{expt.}$, x_i is an outlyer. Replace it with the mean of the two adjacent points.

   c) When all outlyers are replaced, calculate new σ_{FD} and compare with $\sigma_{expt.}$. If the criterion of 2a is met, go on to next N points. However,

   d) If still $\sigma_{FD} > z_1 * \sigma_{expt.}$, use the following extrapolation technique to clean up the data. Fit a curve through the N-1 previous points. Extrapolate this curve through the first five points in the region of interest. Check each of the five actual points against the five extrapolated points.

      If $x_{extrap} - z_2 * \sigma_{expt.} < x_{actual} \leq x_{extrap} + z_2 * \sigma_{expt.}$, the actual point is accepted; if not, replace x_{actual} by x_{extrap}. Calculate a new σ_{FD} and check it. If now O.K., go on after replacing $\sigma_{expt.}$ by σ_{FD}.

      If the new σ_{FD} is worse than the old, increase the order of the curve fit and try the same five points again. And if still

no good, keep the original five actual points and try the next five, and so on.

If the new σ_{FD} is better than the old, but still not good enough, the five corrected points plus the previous N-6 points are used to fit a new curve and the new curve is extrapolated to the next five points. This sliding fit method is continued through the set of N points. Up to M points may be replaced this way before getting an error message out.

3. Whenever σ_{FD} meets the desirability criteria described above (i.e., $\sigma_{FD} \leq z_1 * \sigma_{expt.}$), $\sigma_{expt.}$ is replaced by σ_{FD} before considering the next set of N points. This allows the noise level to increase or decrease throughout a run.

APPENDIX A

MADS SPECIFICATIONS

Inputs:

Analog - Provision for 44 differential input signal conditioners
- 8 synchro, 3 wire

Digital - Flight I.D. - 15 bits
- Events - 15 bits

Signal Levels:

Analog - ±10 mv to ± 5 volts full scale

Synchro - nominal 11 volt, 3-wire, 400 Hz
(Provision for gain adjustment on analog inputs.)

Offset Control:

Provision for amplifier offset of one-half scale to accommodate unipolar inputs

Source Impedance:

0 to 5 K ohms

Input Impedance:

100 K ohms minimum (differential and common mode) on analog inputs and line-to-line on synchro inputs

System Linearity:

± 0.05%

System Accuracy:

Overall accuracy - all effects combined, long term, without adjustment:

a) over any 80° C span within the operating temperature range -
Gain set for full-scale digital counts with 10 mv input signal -
± 1.0% of full-scale counts.

b) over any 20° C span within the operating temperature range -
Gain set for full-scale counts with 10 mv input signal -
± 0.25% of full-scale counts.

c) Calibration Voltage: 0.05% accuracy over all environment and input power conditions.

Calibration System:

Provision for switching signal conditioners to a two-step voltage calibration with provision for two voltage divider resistors and two trans-

ducer simulator resistors for each analog input. Initiation of calibration sequence by an external contact closure or push-button switch actuation.

System Noise:
± 1/2 least significant bit with stable D. C. applied to input.

Input Filtering:
Differential inputs - Low-pass, 5 Hz cutoff (-3db), 18 db/octave attenuation, Butterworth design.

Maximum Common Mode Voltage:
5 volts

Common Mode Rejection:
80 db at 400 Hz with 1000 ohm un-balance

Overvoltage:
Provision for ± 35 volts on all signal inputs without damage or equipment malfunction for more than 0. 5 seconds after removal of overvoltage.

Sample Rate:
128 samples per second

Bits Per Analog Data Sample:
11

Tape Characters Per Analog Data Sample:
2 (one 6-bit and one 5-bit)

Frame Format:
Per diagram

Frame Rate:
Switch selectable at 120, 60, 12, 4, 2, 1 frames per minute, or one frame per two minutes.

Frames Per Tape Record:
Fifteen

Digital Clock:
24-hour time code in one-half second increments. Clock and internal battery removable for remote setting.

Timing Accuracy:
± 3 milliseconds in 5 minutes, ± 0.5 seconds in 24 hours.

Bit Error:
Less than 1 in 10^6 bits.

Tape Width:
1/2 inch, nominal

Tape Thickness:
1.5 mils, nominal

Tape Length:
1200 feet

The following eight characteristics are compatible with all IBM seven-track tape handlers:

Tape Reels:
8-1/2 inch

Recording Technique:
NRZI

Character Density:
556 characters per inch

Tape Tracks:
Seven

Parity:
Odd

Inter-Record Gap:
LRC and gap inserted in 60 msec after every 15th frame

End-of-File:
Gap and mark on manual switch command

Bit Skew:
Maximum total 515 microinches

Tape Modes:
Incremental - 500 steps per second; 3/4-inch IR gaps in 60 milliseconds
Fast Forward and Rewind

Tape Mode Selection:
Electrically switchable

Primary Power:
200/115 V, 400 Hz, 3 φ per MIL-STD-704, Category B

Standby Power:
Internal, rechargeable battery for 60-minute clock operation.

Temperature (Operating and Storage):
Electronics - -54° C to $+71^{\circ}$ C
Tape Transport - -37° C to $+50^{\circ}$ C

Altitude (Operating and Storage):
Electronics - Sea level to 80,000 feet
Tape Transport - Sea level to 80,000 feet

Vibration:
With vibration isolators:

5 to 10 cps	0.08 inch DA
10 to 15 cps	±0.42 g's
15 to 73 cps	0.036 inch DA
73 to 500 cps	±10 g's

Shock:
15 g's, 11 milliseconds

Humidity:
100% relative humidity with condensation. Maximum dew point of 27° C.

Size:
7.4 cubic feet total

Weight:
215 pounds total

System Packaging:
Moisture and RFI sealed containers with quick-operating latches and environmental electrical connectors

EMI:
Designed to conform to MIL-I-6181D

Operator's Controls:
- OFF-STANDBY-RECORD switch
- READY light
- RECORDING light
- Time-of-Day (six-digit, in-line, decimal display)
- EVENT push-button switch

Data Correlation:
18-bit binary time code to drive lamp display (5 V, 75 ma.)

Electronics:
All solid state silicon devices, integrated circuits where feasible

PLAY-BACK EQUIPMENT

Tape Transport

Tape Width:
1/2 inch, nominal

Tape Thickness:
1.5 mils, nominal

Tape Length:
1200 feet minimum

Tape Reels:
8-1/2 inch IBM compatible

Play-Back:
Capable of play-back of tapes recorded on the airborne tape transport at approximately 25 inches per second

Power:
115 V, 60-400 Hz, 1 phase

Electronics Unit

Inputs:
Data input from airborne electronics or from ground tape machine. A separate input from the airborne digital clock to the time display is provided for checking the clock.

Decommutator Rate:
Real time character rates as specified for airborne system or play-back of these at 25 inches per second tape speed.

Frame Synchronization:

Derived from inter-record gaps in data format.

Time Display:

Six-digit decimal, one-plane display in 24-hour time code (hours - minutes - seconds)

Data Display:

Four-digit decimal, one-plane display, switch assignable to any of 52 data channels or any of eight calibration switches.

Event Display:

30-lamp display for flight I. D. and events.

Calibration Switches:

Eight sets, each with seven-bit positions for low calibration and for maximum calibration steps; all sets switched to low calibration, maximum calibration, or decommutator output by a common, remote control. Each set of switches assignable to any of the 52 decommutator data outputs by means of thumbwheel switches.

Analog Outputs:

Eight analog outputs with full digital count (2048) yielding 5 volts into 10 K ohms, single ended. Digital-to-analog converters to convert seven most significant bits.

Analog Filters:

Each of the eight analog outputs has low-pass Butterworth filters with cutoff at 5 Hz and 12 db/octave attenuation.

Character Output:

Square wave 5 volts into 10 K ohms, one cycle per 67 tape characters, 5 μsec minimum duration.

Event Outputs:

Nine event signals, 28 volts into 200 ohms, each switch selectable from one of fifteen event channels.

Power:

115 V, 60-400 Hz, one phase

Packaging:

Portable carrying case with hinged cover over display, connectors, and controls. Unit is weatherproof with cover closed.

APPENDIX B

INPUT LISTING

The following is a listing of a typical set of input data cards for the MADS-1 routine. The calibration curves being input in this case are:

CALNO	=	1	accelerometer
	=	2	coarse air speed
	=	3	drift angle
	=	4	ground speed
	=	5	temperature
	=	6	coarse altitude
	=	7	fine altitude (segmented)
	=	8	magnetic heading
	=	9	fine air speed (segmented)

```
UNPACK
DATE=0 INCR=0 PRINT='SAMPLE'
CALIBRATE
CALNO=1,LENGTH=3,LOCAL=0.,HICAL=2048.
 1X       0    1024    2048
 1Y -0.001     0.0   0.001
VARNO=28,CURVE=1
CALNO=2,LENGTH=19,LOCAL=11.,HICAL=2026.
 2X     11.   111.8   212.5   313.3   414.0   514.8   615.5   716.3   817.0   917.8  1018.5
 2X  1119.3  1220.0  1370.8  1421.5  1522.3  1623.0  1723.8  1764.1
 2Y      41      80     110     140     168     197     224     252     279     306     333
 2Y     360     387     414     442     470     498     526     540
VARNO=4,CURVE=2
CALNO=3,LENGTH=10,LOCAL=0.,HICAL=2040.
 3X     626     944     943    1050    1156    1255    1367    1479    1602    1706
 3Y     -20     -12      -8      -4       0       4       8      12      16      20
VARNO=10,CURVE=3
CALNO=4,LENGTH=11,LOCAL=0.,HICAL=2040.
 4X     344     510     677     845    1011    1177    1342    1510    1676    1844    2009
 4Y     100     150     200     250     300     350     400     450     500     550     600
VARNO=9,CURVE=4
CALNO=5,LENGTH=12,LOCAL=25.,HICAL=2028.
 5X      14     130     279     442     603     777     949    1137    1333    1537    1750
 5X    1970
 5Y      40      30      20      10       0     -10     -20     -30     -40     -50     -60
 5Y     -70
VARNO=13,CURVE=5
```

```
CALNO=6,LENGTH=19,LOCAL=12.,HICAL=2025.
 6X    52.3   112.7   213.3   314.0   414.6   515.3   615.9   716.5   817.2   917.8  1018.5
 6X  1119.1  1219.8  1320.4  1421.1  1521.7  1622.4  1723.0  1783.4
 6Y    0.05     3.1     7.2    11.5    15.8    19.9    23.8    28.0    31.8    35.9    40.0
 6Y    44.0    48.8    53.1    57.9    62.1    67.0    71.2    74.0
VARNO=12,CURVE=6
CALNO=7,LENGTH=21,LOCAL=13.,HICAL=2025.,PARTS=9
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   -1.45   -0.83   -0.35    0.12    0.59    1.02    1.49    1.92    2.39    2.80    3.21
 7Y    3.61    4.01    4.42    4.82    5.25    5.66    6.08    6.49    6.90    7.30
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y    7.35    7.79    8.21    8.65    9.09    9.51    9.93   10.35   10.78   11.19   11.59
 7Y   12.00   12.40   12.79   13.19   13.59   13.99   14.35   14.72   15.12   15.50
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   15.58   16.02   16.49   16.91   17.32   17.75   18.15   18.55   18.97   19.37   19.78
 7Y   20.18   20.52   20.91   21.31   21.70   22.10   22.48   22.83   23.20   23.59
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   23.80   24.20   24.60   25.00   25.40   25.80   26.20   26.60   27.01   27.41   27.82
 7Y   28.22   28.23   29.01   29.41   29.80   30.19   30.52   30.90   31.28   31.60
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   31.82   32.21   32.60   33.00   33.39   33.78   34.15   34.52   34.91   35.30   35.70
 7Y   36.08   36.48   36.85   37.23   37.61   38.00   38.40   38.80   39.19   39.57
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   39.91   40.31   40.71   41.12   41.52   41.99   42.40   42.81   43.21   43.61   44.02
 7Y   44.45   44.89   45.29   45.70   46.12   46.58   47.00   47.49   47.95   48.4
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   48.60   49.01   49.49   49.90   50.35   50.80   51.25   51.70   52.19   52.61   53.10
 7Y   53.51   53.99   54.41   54.89   55.31   55.78   56.20   56.60   57.05   57.41
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   57.70   58.28   58.59   59.01   59.48   59.91   60.38   60.82   61.29   61.72   62.20
 7Y   62.70   63.18   63.61   64.10   64.52   65.00   65.41   65.85   66.23   66.60
 7X    13.0   113.6   214.2   314.8   415.4   516.0   616.6   717.2   817.8   918.4  1019.0
 7X  1119.6  1220.2  1320.8  1421.4  1522.0  1622.6  1723.2  1823.8  1924.4  2025.0
 7Y   66.85   67.31   67.80   68.28   68.76   69.21   69.70   70.11   70.55   70.99   71.40
 7Y   71.81   72.21   72.65   73.05   73.58   73.89   74.29   74.68   75.05   75.41
VARNO=11,CURVE=7
CALNO=8,LENGTH=13,LOCAL=0.,HICAL=2040.
 8X       6     172     346     515     682     853    1021    1188    1362    1530    1700
 8X    1874    2038
 8Y     300     270     240     210     180     150     120      90      60      30       0
 8Y     -30     -59
VARNO=50,CURVE=8
CALNO=9,LENGTH=32,LOCAL=14.,HICAL=2026.,PARTS=9
 9X    14.0    98.5   102.5   112.6   114.6   124.7   134.7   144.8   154.8   164.9   175.0
 9X   185.0   195.1   215.2   315.8   416.4   517.0   617.6   718.2   818.8   919.4  1020.0
 9X  1120.6  1221.2  1321.8  1422.4  1523.0  1623.6  1724.2  1824.8  1925.4  2026.0
 9Y  -.0001       0      20      30    30.5    35.5      39    41.5    43.2    45.5   46.55
 9Y    47.5    48.5   50.05      57      62      66    69.3    72.5    75.5    78.3    81.2
 9Y      84    86.8    89.5    92.3      95    97.5     100   102.5   105.3   107.5
 9X    14.0    98.5   102.5   112.6   114.6   124.7   134.7   144.8   154.8   164.9   175.0
 9X   185.0   195.1   215.2   315.8   416.4   517.0   617.6   718.2   818.8   919.4  1020.0
 9X  1120.6  1221.2  1321.8  1422.4  1523.0  1623.6  1724.2  1824.8  1925.4  2026.0
 9Y   109.5   112.3   112.4   112.7   112.8   113.1   113.4   113.8   114.1   114.4   114.7
 9Y   115.0   115.4     116     119   122.2   125.1   128.2   131.2     134     137     140
 9Y   142.8   145.5   148.3     151   153.8   156.5   159.2   161.8   164.2   167.2
 9X    14.0    98.5   102.5   112.6   114.6   124.7   134.7   144.8   154.8   164.9   175.0
 9X   185.0   195.1   215.2   315.8   416.4   517.0   617.6   718.2   818.8   919.4  1020.0
 9X  1120.6  1221.2  1321.8  1422.4  1523.0  1623.6  1724.2  1824.8  1925.4  2026.0
 9Y   168.8   171.1   171.2   171.4   171.5   171.8   172.0   172.3   172.6   172.9   173.1
 9Y   173.4   173.7   174.2     177   179.8   182.5   185.4   188.2     191     194   196.6
 9Y   199.5   202.3     205   207.6   210.4     213   215.5   217.8   220.3   222.6
 9X    14.0    98.5   102.5   112.6   114.6   124.7   134.7   144.8   154.8   164.9   175.0
 9X   185.0   195.1   215.2   315.8   416.4   517.0   617.6   718.2   818.8   919.4  1020.0
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9X 1120.6 1221.2 1321.8 1422.4 1523.0 1623.6 1724.2 1824.8 1925.4 2026.0
9Y  223.6  226.[illegible]  226.2  2[illegible].4  226.5  226.8  227.1  227.4  227.7  228.0  228.3
9Y  228.6  228.[illegible]  229.5  232.4  235.1    238    240  243.5  246.3    249  251.4
9Y  254.5  257.[illegible]  259.6  262.5    265  267.5    270  272.5    275  277.4
9X   14.0   [illegible]  102.5  112.6  114.6  124.7  134.7  144.8  15[illegible]  164.9  175.0
9X  185.0  195.[illegible]  215.2  315.8  416.4  517.0  617.6  718.2  818.8  919.4 1020.0
9X 1120.6 1221.[illegible] 1321.8 1422.4 1523.0 1623.6 1724.2 1824.8 1925.4 2026.0
9Y    279  281.[illegible]  281.5  2[illegible].7  281.8  282.1  282.4  282.7  28[illegible]  283.3  283.6
9Y  283.9  284.[illegible]  284.6  287.5  290.2    293  295.6  298.5  301.2    304  306.8
9Y  309.5    312  314.5  317.2  319.5  322.4    325  327.5    330  332.3
9X   14.0   93.[illegible]  102.5  112.6  114.6  124.7  134.7  144.8  15[illegible]  164.9  175.0
9X  185.0  195.   215.2  315.8  416.4  5[illegible].0  617.6  718.2  818.8  919.4 1020.0
9X 1120.6 1221.[illegible] 1321.8 1422.4 1523.0 16[illegible].6 1724.2 1824.8 1925.4 2026.0
9Y  333.5  33[illegible]  336.1  33[illegible].4  336.5  3[illegible].8  337.1  337.4  337.7  338.0  338.3
9Y  338.6  33[illegible]  337.5  342.3    345  347.8  350.5  353.3    356  358.5  361.2
9Y  363.4  36[illegible]    369  371.5    374  37[illegible].6  379.5    382  38[illegible]  387.2
9X   14.0   9[illegible]  102.5  112.6  114.6  124.7  134.7  144.8  15[illegible]  164.9  175.0
9X  185.0  195.[illegible]  215.2  315.8  416.4  517.0  617.6  718.2  818.8  919.4 1020.0
9X 1120.6 1221.[illegible] 1321.8 1422.4 1523.0 1623.6 1724.2 1824.8 1925.4 2026.0
9Y  388.5  391.0  391.1  391.4  391.5  391.8  392.0  392.3  392.5  392.8  393.0
9Y  393.3  393.[illegible]    394  396.8  399.5  402.0  404.8  407.4  410.0  412.5  415.3
9Y  418.0  42[illegible]  423.5  426.1  428.4  431.5  434.0  436.8  43[illegible].4  442.0
9X   14.0   99.[illegible]  102.5  112.6  114.6  124.7  134.7  144.8  154.8  164.9  175.0
9X  185.0  195.[illegible]  215.2  315.8  416.4  517.0  617.6  718.7  818.8  919.4 1020.0
9X 1120.6 1221.[illegible] 1321.8 1422.4 1523.0 1623.6 1724.2 1824.8 1925.4 2026.0
9Y  443.5  445.   [illegible]  [illegible]  [illegible]  [illegible]  446.6  447.1  447.4  447.7  447.9
9Y  448.2  448.[illegible]  449.0  451.6  454.3  457.[illegible]  459.5  462.3  465.0  467.8  470.5
9Y  473.3  476.[illegible]  478.5  481.3  484.0  48[illegible].5  489.8  492.0  494.[illegible]  497.1
9X   14.0   98.[illegible]  102.5  112.6  114.6  124.7  134.7  144.8  154.8  164.9  175.0
9X  185.0  195.1  215.2  315.6  416.4  517.0  617.6  718.2  818.8  919.4 1020.0
9X 1120.6 1221.[illegible] 1321.8 1422.4 1523.0 1623.6 1724.2 1824.8 1925.4 2026.0
9Y  497.8  500.[illegible]  50[illegible].3  500.5  500.6  500.9  501.2  501.5  501.8  502.1  502.3
9Y  502.6  502.[illegible]  503.5  506.3  509.3  512.0  514.8  517.5  52[illegible].5  523.3  526.0
9Y  528.8  531.[illegible]  534.3  537.1  539.9  542.7  545.5  548.2  551.0  553.8
VARNO=2,CURVE=9
EVNTND=1,EVENT='FILOT',EVNTNO=4,E.[illegible]='DOPPLR'
PARAM='PRINT'
PARAM='EXEC'
NSEG=2
  SEG1=6,SEG2=7,SEGLIM=4.8,SEGCON=1000.
SEG1=2,SEG2=9,SEGLIM=27.,SEGCON=1.
STOP
```